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RADON IN SCHOOL WELL WATER: CASE STUDIES AND MITIGATION IMPLICATIONS

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ABSTRACT

A survey of waterborne radon was carried out in schools, participating in the Connecticut School Testing Program (STP), that relied on wells as their source of water. Previous studies had measured both radon in air and water sources in these schools. In this study the contribution of radon in water to radon in air concentrations within school shower facilities was evaluated. The use of appropriate radon in water mitigation systems for these schools and the public health implications of these findings are discussed.

INTRODUCTION

A concern of state health departments or others involved in the assessment of radon in schools is the contribution of radon in water sources. These sources have proven to be a major contributor to both the ingestion and inhalation radon exposure in main occupied buildings in Connecticut. For example, approximately one third of residential structures in Connecticut utilize private wells as their source of water. Radon concentrations in some of these wells exceeds 500,000 picocuries per liter (pCi/L) [18,500,000 becquerels per cubic meter (Bq/m^3)]. In some towns public water supplies are absent or not available in areas where schools are located.

To date, the Connecticut Department of Public Health and Addiction Services has completed four phases of its School Testing Program (STP). In this Program 205 schools in 31 municipalities have been evaluated for the presence of radon (Siniscalchi et al.1992A). The results of the screening tests for these schools are summarized on Table 1. Twenty-four of these schools located in nine municipalities utilize private wells as the source of drinking water.

The radon concentrations in these wells have been shown to range from 135 to 18,648 pCi/L (4,995 to 689,976 Bq/m^3). The results of the radon in water analysis of these schools are summarized on Table 2. Since the majority of screening tests conducted on these schools took place on weekends or during school vacations the contribution of these water sources to the air radon levels was not known.

The Radon Program had received numerous inquiries from local education and health officials on the significance of the radon in water levels. These officials raised questions about proposed federal and state standards, the need to mitigate these wells, and the selection of an appropriate mitigation system.

In order to address these questions the authors decided to conduct a series of monitoring experiments in a representative sample of schools that utilize wells as their source of water. Four schools with both wells and shower facilities were tested in this study.

MATERIALS AND METHODS

Air concentrations of radon in the locker room shower areas were actively monitored during the experiments using a Niton RAD7® monitor. The Niton RAD7® operated in the "sniff" mode which reports radon concentrations every five minutes. The inlet for the monitor was placed at a height of five feet among the shower units. With the locker room doors and windows closed, the Niton RAD7® measured backgound radon concentrations for 30 minutes before the showers were turned on. Then, between five and eight showers were turned on (cold water) for 15 minutes. The Niton recorded the radon concentrations in the air during this time, and continued readings for an additional 30 minutes. Ventilation conditions in the locker rooms were noted.

Water samples were collected according to EPA guidelines. (EPA 1978) The original water samples were taken in duplicate from a well sample source faucet. Samples were collected after a 5-10 minute flushing time to obtain maximum radon well concentrations. Water samples were collected, in duplicate, from a sink in the locker room both before and after the showers were used. In addition, water samples were taken before the showers ran from the faucet determined to the closest to the well source.

Water samples were analyzed by the Department of Public Health and Addiction Services Bureau of Laboratory Services. An additional water sample, taken after the showers ran from the locker room sink, was analyzed using the Niton RAD7®/H_20 adapter. The results from the locker room testing are presented in Table 3 and Fig. 1-4.

Classroom air concentrations of radon were analyzed using passive activated charcoal, charcoal liquid scintillation, and various electret ion chamber detectors; according to the manufacturer's directions.

RESULTS

Table 1 summarizes the radon in air screening values obtained to date. These results indicate a wide range of number and percentage of schools with rooms requiring confirmatory testing. For example, some towns were found to have all (100%) of their schools with at least one room in excess of 4 pCi/L.

Table 2 presents the results of radon water screening measurements obtained to date in the STP. At this time, 28 wells have been sampled in 25 school buildings in 9 towns. There appears to be a wide range of radon values found in the school wells. The lowest value discovered was 135 pCi/L (5M in Town "D"), while the highest value was 18,648 pCi/L (school 4E in Town B). The mean radon level was 4,723 pCi/L, which is significantly higher than the geometric mean Connecticut well water radon level of 3,000-3,300 pCi/L. A total of eight of the wells tested had radon water values above the Connecticut geometric mean value, 17 of the wells tested had radon water values below the Connecticut geometric mean level, while only one well was at the average value.

School B1H had relatively low concentrations of both radon in air and radon in water (see Table 3 and Fig. 1). Background air reading in the locker room demonstrated an average radon level of 2.18 pCi/L. The locker room doors and windows were closed, with no observable ventilation system operating. Background water measurements reported 653 pCi/L at the faucet closest to the well and 202 pCi/L at the locker room sink. The Niton RAD7®was positioned in the center of a row of five showers. While the showers ran, the air concentrations of radon remained unchanged. The showers in this locker room were equipped with automatic shut-off and were reset approximately every minute. Therefore, it is clear that the showers did not run continuously. After the showers were turned off, the air readings of radon remained unchanged (Fig. 1). The mean water sample, drawn from the locker room faucet 30 minutes after the showers were turned off, measured 356 pCi/L (see Table 3).

The locker room in School R18H had closed doors and windows, but a ventilation system was in use during the experiment. Background air concentrations of radon were low, 0.5 pCi/L. Water samples obtained at the site of the water holding tank measured 10,845 pCi/L. However, water sampled from the locker room drinking fountain were much lower, 434 pCi/L. During the 20 minutes that a carousel of six showers ran, the radon in air concentrations rose from undetectable levels to 16.4 pCi/L. After the showers were turned off, the air reading dropped from 15.3 pCi/L to 1.09 pCi/L within a 20 minute period (see Table 3 and Fig. 3). The effect of running the showers for 20 minutes increased the radon in water concentration in the locker room drinking fountain to 4,341 pCi/L, a ten-fold increase over the initial measurement (see Table 3).

School D7H had the highest well water concentration of radon of the four schools analyzed. Throughout the duration of the monitoring at this school, construction projects were occurring in most areas, including the locker room. A large fan was being used approximately 20 feet away from the shower sampling location. The background air concentrations of radon in the locker room, measured before the showers were turned on, ranged between undetectable levels-1.9 pCi/L. During this period, water samples were obtained. At the faucet nearest the well, the water recorded 10,629 pCi/L of radon. The water sampled in the locker room sink measured 11,280 pCi/L. After 30 minutes of background measuring, the showers were turned on. The Niton RAD7® monitor was located in the middle of a row of eight showers. The showers ran on cold temperature for fifteen minutes. While the showers were on, the air levels of radon increased from undetectable levels to 6.55 pCi/L. When the showers were turned off, the air readings continued to rise to a peak concentration of 14.2 pCi/L, after which they decayed back down to undetectable levels pCi/L within 15 minutes (see Fig. 2). Water samples collected 30 minutes after the showers were turned off reported a mean radon concentration of 12, 081 pCi/L (see Table 3).

The locker room in school B28M had closed doors and windows during the shower room monitoring, with no observable ventilation system operating. The ambient air concentrations of radon were very low, 0.44 pCi/L, during the 30 minute background sampling period. While the seven showers were operating, the radon concentration in air increased slightly to 0.73 pCi/L. When the showers were turned off, the level peaked at 7.64 pCi/L, decayed to 1.09 and then gradually increased up to 6.55 pCi/L (Fig. 4). Water sampling before and after the showers ran demonstrated a slight increase in radon in water concentrations, from 1,225 to 1,276 pCi/L (see Table 3).

DISCUSSION

The studies show that schools with shower facilities utilizing private wells as their source of water can have short-term measurable radon concentrations in areas adjacent to the showers. The post-shower radon concentrations of the four schools appear to vary by both water concentration and shower head efficiency. Peak radon air concentration, ranged up to 17 pCi/L in schools with water levels in excess of 4,000 pCi/L.

The relevance of these short-term peak levels is uncertain. These initial studies suggest that the radon air level dissipate quickly following cessation of showering activity. In fact, the tests showed radon air levels appear to return to normal within one hour in all four schools. To explore the long-term meaning of these contributions additional testing will be necessary. These tests should include assessment of classrooms adjacent to both shower and kitchen facilities.

Radon mitigation may still be needed to control radon ingestion exposure even if the resulting inhalation exposure is low. A number of radon in water mitigation systems are available to control either the inhalation or ingestion exposure to radon water sources. These include activated charcoal and various types of aeration systems. Previous papers by the Connecticut Department of Environmental Protection and the DPHAS Radon Program have reported on the need to conduct multiple samples to assess the average radon levels in consideration of temporal variation issues (Dupuy et al. 1992, McHone et al. 1992, Siniscalchi et al. 1992B). Our studies have also emphasized the need for accurate determination of peak radon levels for selecting the appropriate mitigation system (Dembek et al. 1993).

CONCLUSIONS

These initial studies indicate that inhalation exposure from radon emitted from shower facilities may not result in measurable increase in average radon concentrations in areas beyond the shower facility. However, more tests are needed to confirm these initial findings.

The Connecticut Radon Program is in the process of conducting these additional tests which include: 1.) comparison tests of various shower room configurations, 2.) both short-term and long-term radon in air measurements in rooms adjacent and distant to active shower facilities, and 3.) similar tests in school kitchen facilities.

We also will be testing the effectiveness of various mitigation systems for treating radon in water problems in schools.

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Table 1. Screeing test results of radon in air for STP phases I, II, III & IV municipalities

Town	Device[a]	Period	No. of Schools Tested	Results Recvd.	No. of Rooms Tested	No. of Schools GE[b] 4 pCi/L	Percent Schools GE 4 pCi/L[c]	No. of Rooms GE 4 pCi/L	Percent Rooms GE 4 pCi/L
Phase I.									
A	EIC	7-9/91	8	8	711	6	75%	38	5%
B	EIC, AC	8-9/91	6	6	175	4	67%	18	10%
C	AT	9-11/91	15	15	386	4	27%	10	3%
D	AT, AC	7-11/91	8	8	273	5	63%	33	12%
E	EIC	8/91	1	1	17	0	0%	0	0%
F	AT	8-12/91	6	6	164	4	67%	57	35%
G	EIC	8/91	2	2	60	1	50%	2	3%
H	AT, AC	8-12/91	17	17	713	11	65%	100	14%
Phase II.									
I	AC	12/91	1	1	53	1	100%	7	13%
J	LS	2/92	1	1	31	1	100%	1	3%
K	LS, AC	2/92	5	5	196	2	40%	9	5%
L	LS	2/92	2	2	143	1	50%	1	1%
M	AC	2/92	4	4	69	2	50%	3	4%
N	AC	2/92	8	8	197	4	50%	13	7%
O	AC	2/92	6	6	130	6	100%	58	45%
P	AC	2/92	10	10	300	4	40%	14	5%
Phase III.									
Q	AC	2/93	3	3	320	1	33%	1	0%
R	LS	4/93	6	6	307	6	100%	70	23%
S	LS	4/93	5	5	387	4	80%	53	14%
T	LS	4/93	3	3	187	1	33%	8	4%
U	LS	4/93	2	2	125	2	100%	4	3%
V	LS	4/93	7	7	267	7	100%	134	50%
W	AC	4/93	5	5	169	1	20%	1	1%
X	AC	4/93	6	6	601	3	50%	19	3%
Y	AC	4&11/93	1	1	92	1	100%	2	2%
Phase IV.									
Z	AC,LS	10/93 & 3/94	2	2	56	0	0%	0	0%
AA	LS	12/93	7	7	250	3	43%	6	2%
AB	AC	12/93	30	30	843	15	50%	81	10%
AC	AC	2/94	16	16	616	2	13%	7	1%
AD	AC	4/94	6	6	282	2	33%	4	1%
AE	AC	2/94	1	1	31	0	0%	0	0%
AF	LS	2/94	4	4	162	2	50%	5	3%

[a] AC = activated charcoal, AT = alpha track, EIC = electret-ion-chamber, LS = liquid scintillation

[b] GE = greater than or equal to

[c] percent of schools with at least one room with radon levels greater than or equal to 4 pCi/L

Table 2. Results of screening and follow-up radon in water sampling in Connecticut schools

Location		Schools using Private Well Water	Screening School Well Mean Radon Level (pCi/L)[b]	Follow-up School Well Mean Radon Level (pCi/L)[b]	Water Use	
Phase[a]	Town				Presence of Showers[c]	Showers Used[d]
I.	B	1H	945	653	Y	N
		2E	1,935	NT[e]	N	
		3E	12,990	NT	N	
		4E	18,648	NT	N	
		28M[f]	NT	1,371	Y	N
	D	5M	135	NT	Y	N
		6E	3,085	NT	N	
		7H	14,084	10,629	Y	N
	F	8E	223	NT	N	
		9H	893	NT	Y	N
		10E	1,570	NT	N	
		11E	5,183	NT	N	
II.	I	12M	9,470	NT	Y	N
III.	Y	13E	2,328	NT	N	
	R	14M	469	NT	Y	Y
		15E	545	NT	N	
		16E	2,080	NT	N	
		17	11,815	NT		
		18H	12,990	10,845	Y	Y
		19E	16,820	NT	N	
	U	20E	1,215	NT	N	
IV.	Z	21E	1,794	NT	Y	N
		22E	2,494,[g] 2,515	NT	Y	N
	AD	23E	1,981	NT	N	
		24E	2,494	NT	N	

[a] Of STP, i.e, Phase I, 1990-91, Phase II = 1991-92, Phase III 1993, Phase IV 1993-1994
[b] Mean value for split sample of each school well.
[c] Showers facility present = Y, showers not present = N
[d] Showers frequently used = Y, not frequently used = N
[e] Not tested
[f] Not a private well
[g] Two wells supply this school

Table 3. Radon in air and water variations in public school wells

	Before Showers Were Turned On			Showers On	After Showers Were Turned Off		
Schools	Faucet Nearest to Well Rn conc. (pCi/L)	Locker Rm. Aver. Rn in Water conc. (pCi/L)	Locker Rm. Aver. Rn in Air conc. (pCi/L)	Locker Rm. Aver. Rn in Air conc. (pCi/L)	Locker Rm. Aver. Rn in Water conc. (pCi/L)	Niton Rn in Water conc. (pCi/L)	Locker Rm. Aver. Rn in Air conc. (pCi/L)
B1H	653 ± 6%	202 ± 15%	2.18 ± 321%	1.82 ± 344% Peak 2.18 ± 274%	356 ± 9%	95 ± 49%	1.82 ± 395% Peak 4.37 ± 162%
D7H	10,629 ± 0.9%	11,280 ± 0.9%	0.87 ± 342%	2.91 ± 198% Peak 6.55 ± 122%	12,081 ± 0.9%	11,300 ± 6%	3.46 ± 158% Peak 14.2 ± 73%
R18H	10,845[a] ± 16%	434 ± 7.4%	0.5 ± 483%	6.55 ± 150% Peak 16.4 ± 66%	4341 ± 1.6 %	1910 ± 6%	5.10 ± 265% Peak 15.3 ± 69%
B28M[b]	1,371 ± 3.2%	1,225 ± 3.5%	0.44 ± 274%	0.73 ± 483% Peak 1.09 ± 483%	1276 ± 3.4%	1220 ± 6%	4.37 ± 219% Peak 7.64 ± 109%

[a] at top of holding tank, not faucet nearest well
[b] not a private well, uses town water supply

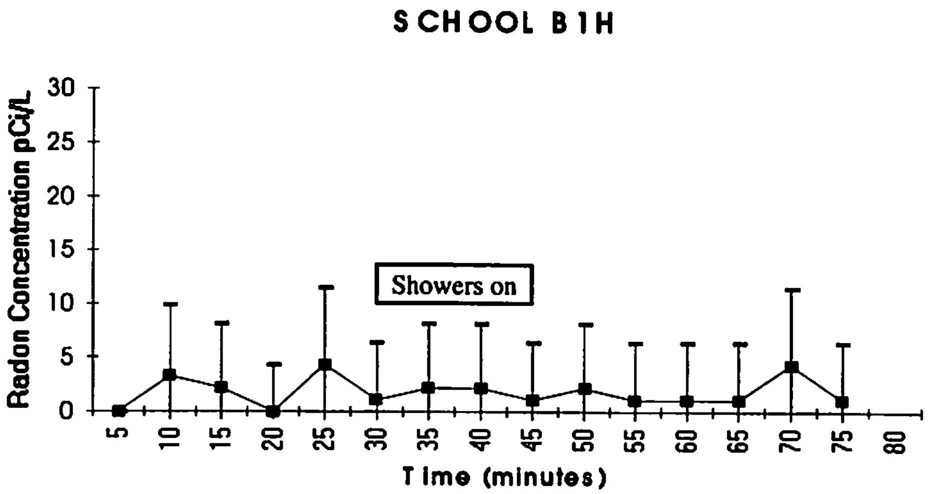

Fig. 1. Radon air concentrations from shower usage in school B1H

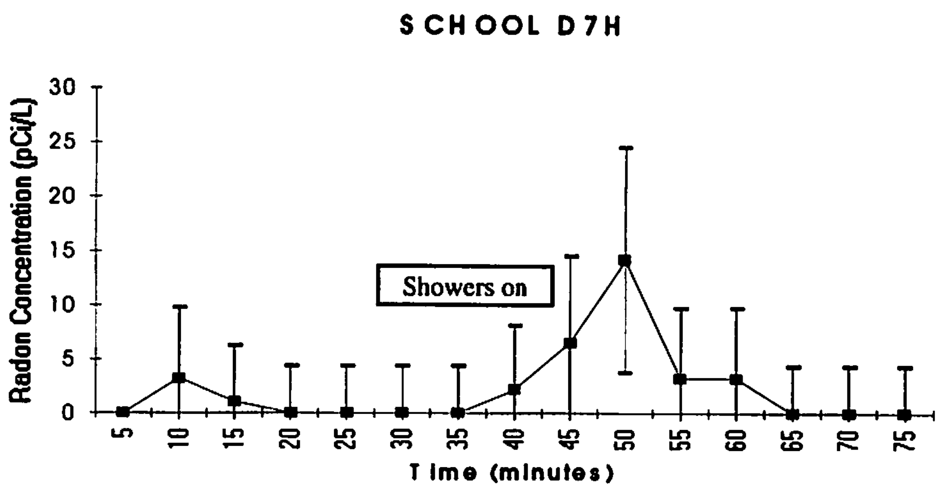

Fig. 2. Radon air concentrations from shower usage in school D7H

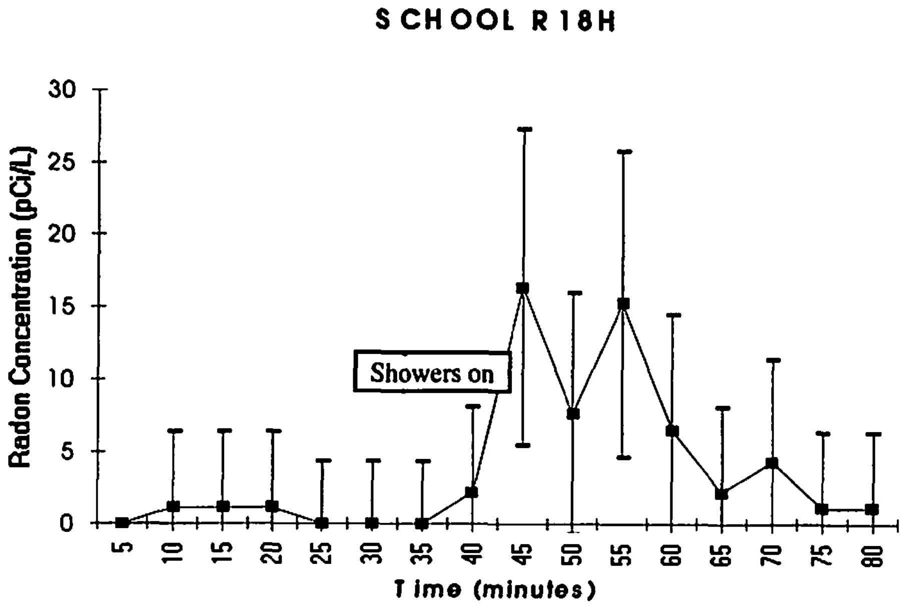

Fig. 3. Radon air concentrations from shower usage in school R18H

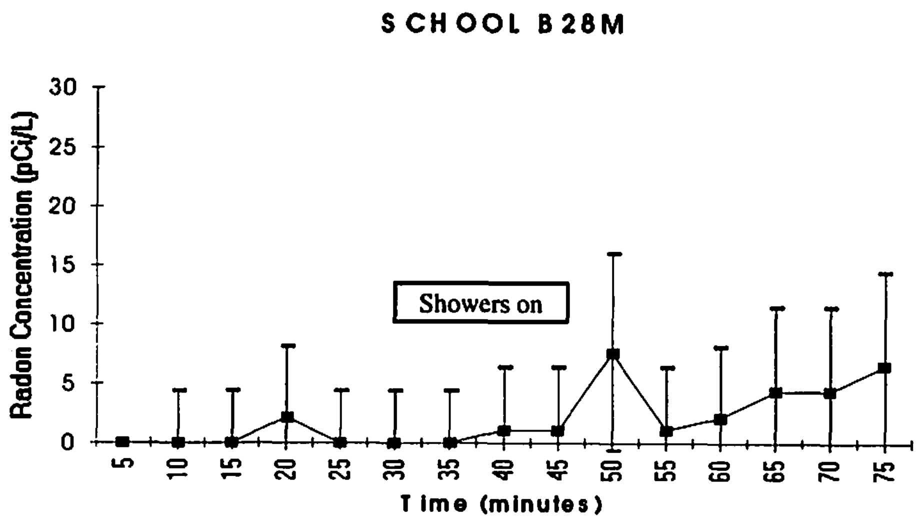

Fig. 4. Radon air concentrations from shower usage in school B28M